Stochastic cooling overview

During this coming run (FY04) we plan to implement Palmer cooling on a single bunch in the yellow ring.

There is a horizontal pickup near the downstream Q4 in section 12 and a longitudinal kicker near the upstream Q4 in section 4.

The net delay for the beam is 8us and the signal propagation time (going upstream) is 6us.

The main idea in Palmer cooling is to use a horizontal difference signal in a dispersive region to get information about the momentum distribution.

$$x = \hat{x}_\beta \cos(\psi_\beta) + D_x(s)\Delta p / p$$

The ratio of betatron amplitude to dispersive amplitude reduces the effective cooling power by a fraction

$$R \approx \frac{\sigma_\beta^2}{\sigma_\beta^2 + D_x^2(\Delta p / p)^2}$$

For 1 mm rms betatron size and 1.e-3 rms momentum spread R=0.5 for a dispersion of 1 meter.

Stochastic cooling study goals for FY04

Hardware work needed for ? months before starting.

1) time in signals and align filters
2) implement power compression
   waveguide with v = v(f) after amplifier to reduce instantaneous power requirements

No dedicated beam time requested if witness bunch implemented.

1) single bunch transfer function measurements
2) adjust timing
3) measure cooling of a single bunch, perhaps need lower intensity (1.e8)

Modeling

1) estimate of cooling time for actual setup
2) inclusion of realistic transfer function in Fokker-Planck (FP) code
3) quantitative agreement between FP code and experiment
4) collective effects?

Impedance and instability studies:
Measure coherent synchrobetatron spectrum using PLL
Classic example for coherent response of a group of oscillators is

$$\frac{d^2 x_j}{dt^2} + \omega_j^2 x_j = \sum_k \left(W x_k + \alpha \frac{dx_k}{dt} \right) + F_0 \sin(\omega t)$$

$$signal(t) = \sum_k x_k(t) = R(\omega)\cos(\omega t) + X(\omega)\sin(\omega t)$$

All the oscillators are driven and respond to some degree.
By varying the frequency we can get the frequency distribution of the oscillators. By varying the total charge we can get W and alpha.
For bunched beams the equations are more complicated but the principle is the same.

For bunched beams without detuning, one may obtain a linear, inhomogeneous, PDE. The unknown is the average, transverse offset as a function of the longitudinal variables and the time. The equation can be made first order by assuming the betatron tune shift small compared with the tune (Q=28). For space charge and a short range resonator wake it is: (dimensionless variables)

$$\frac{\partial x(\varphi, p, t)}{\partial t} + p\frac{\partial x}{\partial \varphi} - \sin(\varphi)\frac{\partial x}{\partial p} = i\Delta Q_{sc}(\varphi)[x(\varphi, p, t) - \bar{x}(\varphi, t)]$$

$$+ iW_0 \int_0^{\varphi} I(\varphi_1)\bar{x}(\varphi_1, t)\sin[\tilde{Q}(\varphi - \varphi_1)]\exp[-Q_e(\varphi - \varphi_1)/2Q_r]d\varphi_1$$

$$+ i\xi x(\varphi, p, t) + iF(\varphi)\exp(-i\Delta\omega t)$$